A Simple Regenerative Vacuum Device and Some of its Applications

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XX. *A Simple Regenerative Vacuum Device and Some of its Applications.* By

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ABSTRACT.

The Paper deals with the difficulties arising from residual traces of air fouling the vacuum above the mercury column in syphon gauges and other devices. A remedy is suggested in the form of a small attachment taking the shape of bent capillary tubing ending in a bulb. This enables the air to be repeatedly pushed into the vacuum of this bulb, the mercury at the bottom of the capillary preventing the subsequent return of the air. With such an arrangement fitted to the top of a syphon gauge the height of the column of mercury becomes a true measure of the gas pressure, subject only to the definite correction for the vapour pressure of mercury and temperature. The device is regenerative in the sense that, irrespective of any progressive fouling of the vacuum, a fresh air-free vacuum is automatically created by it every time it is brought into action. As typical examples of the wide field of utility of the device its application to mercury barometers and mercury vapour lamps is also briefly discussed.

ONE of the devices finding constant use in vacuum work is the simple syphon gauge illustrated in Fig. 1 (*a*). The readings of such a gauge are made on the assumption that the space above the mercury in the closed limb is a perfect torricellian vacuum containing nothing but a trace of mercury vapour which, at the average temperature of about 20°C. has a negligible vapour pressure of about 0·001 mm. of mercury. For convenience in measuring the difference of mercury level in the two limbs of the gauge, it is customary to have them side by side. This arrangement introduces difficulties in the way of filling the gauge with mercury without locking any small bubbles of air in the closed limb. In practice even with the best of care small bubbles of air do get locked in the closed limb of the gauge, especially when a vacuum process of filling the gauge with boiling mercury is not adopted. At the first opportunity when the gauge comes under operation these bubbles expand into the torricellian vacuum above the mercury in the closed limb. Considering that the volume available for expansion is generally very small, and that the bubbles to start with are very nearly at atmospheric pressure, it is easy to see that quite small bubbles are enough to cause an error in reading of about 1 mm. When the actual pressure in the system is only a millimetre or two, this is a serious error of about 50 per cent.

Further, the extent of the error due to this is uncertain, and it can be determined only by comparison with another standard connected to the system or by measuring the gas pressure accurately by some other means. Apart from this uncertainty, the error is also variable with the pressure, since the volume of the vacuous space above the mercury varies with the pressure. In addition to these troubles, if the gauge comes into operation frequently and is to be used for a long time connected to an apparatus, there is a progressive deterioration of the vacuum in the closed limb. This is due to the film of air carried along the walls by the mercury flowing in and out of the closed limb periodically. For such gauges it is useful to fit a simple air-trap, as shown in Fig. 1 (*c*), and this would arrest the forward progress of the air film to a great extent.

Because of such inherent defects the syphon gauge has always remained a rough indicator for low pressures, and its readings have never been relied upon to an accuracy greater than a few tenths of a millimetre of mercury. If means can be devised to deal successfully with such accumulations of air fouling the vacuum and ensure the vacuum above the mercury being practically perfect, there is no reason why it could not be used to measure the pressures directly with an accuracy of about 0·001 mm. Its directness and simplicity are greatly in its favour and the limit is set only by the accuracy of the kathetometer used to measure the difference in level.

The simplest way of dealing with such residual gases seems to be that of pushing them out into a subsidiary chamber and preventing their return back into the system. In a syphon gauge this can easily be achieved by attaching the small regenerative extension R, as indicated in Fig. 1(b). This device consists of a small length of capillary tubing T, bent to the shape shown and ending in the auxiliary bulb B.

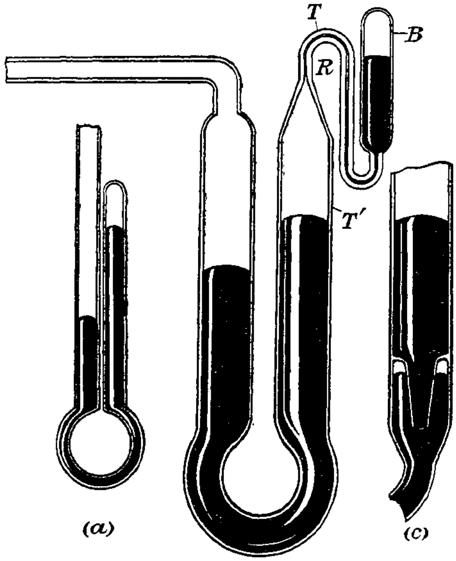

FIG. 1.

To start with, the gauge, including the regenerative attachment, is completely filled with mercury as usual. When it is connected to a low-pressure system mercury level goes down in B and T', forming torricellian vacua in the two chambers. The little mercury that remains in the lower portion of B serves to cut off communication between B and T'. Into this vacuum the residual bubbles of gas locked in the tubes during the filling operations can rise. Now, if the open limb is opened to the atmosphere, the mercury rises up in T' and passes into B, forcing the residual gases above it into B. As the pressure goes down again the mercury level goes down in T', sucking a fresh air-free torricellian vacuum above it. Thus the vacuum above the mercury is practically perfect, and the difference in heights of the mercury in the two limbs is an exact measure of the gas pressure within an accuracy of about 0·001 mm. mercury. The arrangement described is regenerative in the sense that this action is repeated automatically every time the gauge comes into action.

Such a regenerative device is applicable to many laboratory devices in one form or other.

One such principal field of application is supplied by the mercury barometers which, in essentials, are elaborated syphon gauges. As prominently pointed out in the Meteorological Office observers' handbook,* the chief defect of mercury barometers is their gradually increasing error, due to the progressive accumulation of air in the space above the mercury. Considering that a barometer to be of any use for meteorological purposes must be capable of maintaining an accuracy greater than 0·01 mm. for periods reckoned in years, it is easy to see how small and slow a

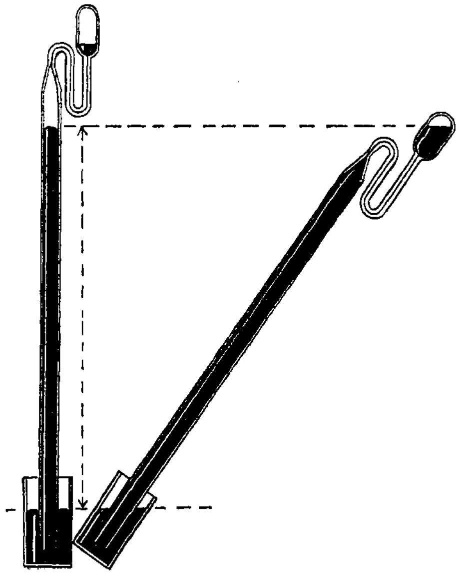

FIG. 2.

leakage is sufficient to make the instrument of no use. A small regenerative attachment of the type described is easily fitted on to a barometer of any pattern, and then it can deal with such accumulations of air quite easily. All that one has to do is to periodically tilt the barometer a little, as shown in Fig. 2, in the case of portable instruments of the Kew pattern, or screw up the base screw in the case of the Fortin type of standard barometers. Especially is this device of value for standard barometers. The device has the great advantage that it is of small dimensions, and can readily be fitted to existing types of barometers without necessitating any serious structural alterations.

Another instance of its application is in the case of a simple type of mercury vapour lamp. In a lamp of the design shown in Fig. 3 the vacuum in the arc space

* 1919 Edition, p. 22.

is automatically renewed every time a little air is let in, and sucked back by a filter pump, or the lamp may be tilted suitably. In fact, the lamp exhausts itself to start with, without the aid of any high vacuum pump. As such it ought to be very useful in many laboratories where the requisite facilities for the production of high vacunm do not exist.

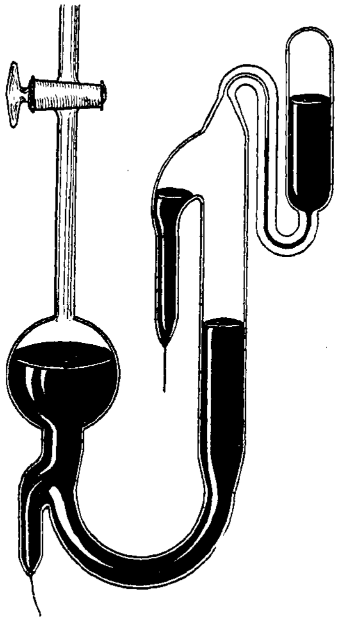

FIG. 3.

Doubtless there are many other similar instances where the principle of the device could be used in one form or other.

In conclusion, I must thank Prof. A. W. Porter, D.Sc., F.R.S., for his sympathetic interest in this device.

DISCUSSION.

Dr. R. T. BEATTY said that the device is a remarkably simple and effective one. If it could be put on the market in combination with an oil trap and a drying tube it would fill a long-felt want.

Dr. G. B. BRYAN said that if the capillary tube were too small there might be difficulty in getting the mercury to move air bubbles along it, as there is a tendency for the mercury to slip past a bubble. He inquired as to the kind of glass employed.

Dr. E. A. OWEN mentioned a somewhat similar device which has been in use for some time at the National Physical Laboratory.

Mr. F. A. GOULD (communicated): The author has drawn attention to a device which has been known for many years to users of precision barometers.

In the " Travaux et Memoires du Bureau International," Tome II (published in 1883), there is a description of a barometer in which practically the same device is used. It is recorded there that the object of the device was not entirely fulfilled to the satisfaction of the Bureau

International, as it was found that "the complete expulsion of the air from the vacuum-space of the barometer required the passage of a considerable quantity of mercury upwards through the instrument, a procedure which probably introduced fresh small bubbles of air from the lower end of the barometer."

The device for renovating the vacuum has also been used in this country. A reference standard mercury barometer incorporating this design was constructed by Dr. Aston, formerly of the Royal Aircraft Factory, Farnborough, during the war, and is still in use at Kidbrooke, while a similar principle was adopted in an experimental standard barometer which, though designed at the National Physical Laboratory in 1913, was not filled until 1922. The efficiency of the device has not yet been tested at the N.P.L.

The reference made by the author to the possibility of securing an accuracy of 0·001 mm. of mercury in the use of a syphon gauge requires some qualification. It is well known that the capillary action of mercury is not negligible, even in tubes of comparatively large diameter, e.g., 1 in. Exact equality in the amount of the capillary depression in each limb of the gauge cannot be relied upon, and it would be necessary to select a syphon tube of internal diameter at least 1·3 in. in order that the differential capillary error should not exceed 0·001 mm. Other causes would render this degree of accuracy difficult to secure.

The reference to the meteorological barometer is misleading, and an estimate of 0·1 mm. would be far nearer the truth than 0·01 mm. for all ordinary purposes. It is usual to insert an air trap in the tubes of all Kew-pattern barometers (i.e., those barometers with uniform, contracted scales and no fiducial point), but it is doubtful whether it would be practicable to fit the "vacuum-renewal" device to the ordinary portable types of mercury barometers.

Mr. J. Guild said that he was particularly interested in the application to mercury lamps and would like to know more of the author's experiences in this connection. The models shown were on a small scale and suitable for low voltages, but where a bright discharge is exacted the vapour pressure of the mercury becomes considerable and it might be expected that in these circumstances the mercury seal would cease to be effective.

Dr. D. Owen asked if the author could furnish some experimental results. Had he, for instance, data of inter-comparison of two syphon barometers constructed as described and subjected to the same conditions?

The Author, in reply to the discussion, said that the device could very readily be combined with an oil trap and drying tube. Various difficulties have to be overcome in practice, but there is none in getting the mercury to move the bubbles provided a capillary tube of 0·5 mm. diameter be used. It was not surprising that the idea should have occurred to others, but he was not previously aware of the fact and had thought that other workers might find the device useful. He had not had an opportunity to obtain experimental data, but he hardly thought a syphon barometer would be capable of a total accuracy of 1 μ. That figure represented the maximum error due to imperfection of the vacuum. The device would not be effective for an indefinite period, but might increase the life of a barometer by some years. The mercury lamps of which he had had experience were some taking 2 amp. at 110 volts which he had made for laboratory use. In such lamps when hot the mercury rises about 1 cm. The construction of the apparatus is such that there is no tendency for the rise in vapour pressure to break the mercury seal.

In regard to the previous work on the subject in France, he concluded from his own inquiries that this had produced but little impression here, and he trusted his Paper would serve to advance the matter.